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XXX.—*Contributions to the History of the Development of the Decapod Crustacea.* By HEINRICH RATHKE*.

ONE of the objects which I had proposed to myself for my tour through Scandinavia and Denmark, was an investigation of the Crustacea as regarded their development. Of Decapods which might serve as subjects for this investigation, several, it is true, fell in my way; fewer, however, by far than I had expected: these were *Astacus marinus*, *Pagurus Bernhardus*, *Galathæa rugosa*, and a crab, which I consider to be *Hyas Araneus*. The details respecting these I design to make known, together with the results of the examination of various other animals, in a separate work; as, however, some time may elapse before its publication, I will here communicate the most essential particulars of what I have learned respecting the development of the above-mentioned Crustacea, in order, as soon as possible, to record a testimony to the correctness of Thompson's discovery, that even the Decapods, after they have already quitted the egg, undergo a very considerable metamorphosis.

1. *Astacus marinus*.—Embryos just on the point of hatching, possess already five pairs of feet, and these are similar in form to those of the full-grown specimens. But to the coxæ of each is attached a part representing a narrow and long appendage of the leg, proceeding down it on its outer side, little inferior to it in length, and composed of two larger members, of which the inferior one again consists of ten smaller articulations, and carries a number of long bristles. The same also is the case with the foot-jaws (Kieferfussen) of the second and third pair, of which, moreover, the hindermost is even at this period the largest of all, and it is evident from this that the above appendix represents the subsequent *palpus flagelliformis*. The four posterior foot-jaws and the ambulatory legs have also in general a resemblance to the legs of the Schizopoda, especially to those of *Mysis*. But this similarity afterwards

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disappears in the ambulatory feet, the appendage which they bear subsequently falling off. The foot-jaws of the anterior pair are already like those of full-grown specimens. Branchiæ are already present on the legs and behind the foot-jaws, but they are still very small, and at the utmost merely provided with small low warts on their surface. The tail or abdomen possesses as yet no false feet, and the fan consists merely of a single almost triangular lamina of considerable size, the posterior margin of which has a slight incisure (ausschnitt), and whose lateral halves are so applied together inferiorly, that they, for the most part, touch each other. The front antenna consists, it is true, of several articulations, but is not yet separated into two branches. The posterior antenna is not much longer, but consists of two branches nearly equal in length, of which the one represents a pretty broad lamina (appendix), the other a cylinder (walze). In front a simple nearly subulate snout proceeds from the cephalothorax, which is, at least, as long as the front or smaller antenna, and curves between the eyes downwards.

2. *Pagurus Bernhardus*.—Embryos about to escape, have only three pairs of members that can serve for locomotion. The front pair is the longest, the central somewhat shorter, the hinder about half as long as the central. This hinder member consists of three articulations unequal in size, but is otherwise simple. On the other hand, each of the four other members consists of a rather long and thickish stem, and of two branches of nearly equal length, which originate near one another at the lower end of the stem, and one of which is situated exteriorly to the other; the outer one is (flat) compressed, and is composed of two articulations, the inner one is cylindrical and composed of five articulations. All these six members are not, as might be expected, true feet in a lower stage of development, but, as will appear hereafter, the foot-jaws; and indeed their maxillæ and mandibulæ are apparent, but they offer nothing particularly remarkable. Of true legs, and also of branchiæ, there does not yet exist a trace. The antennæ are similarly constituted to those in the mature embryos of the Lobster. In front a thin and moderately long snout proceeds from the cephalothorax. The tail is long, thin, and distinctly articulated. False feet are not yet observable. Only the central lamina of the fan is present, and represents a simple lamina narrow in front, posteriorly considerably broad, the two hind corners of which are somewhat rounded, and the posterior margin furnished with a slight incisure. In young, which are $1\frac{1}{2}$ lin. in length, and considerably larger than the mature embryos, the four anterior foot-jaws were of

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the same form as in these, only their stem had become relatively much broader; but on the two posterior ones, which likewise had become relatively longer, an inner branch had already begun to form, but was not yet articulated. Close behind these organs appeared on the inferior side of the cephalothorax two to three pairs of very short but very thick cylindrical and uncinatè (hakenformig) much incurved (zusammengekrümmt) members, of which those of the front pair were slightly swelled at their extremity, and were there provided with a scarcely perceptible incisure; the others, however, appeared quite simple and obtusely rounded at their extremity. These minute organs were the first indications of true legs. There was no sign of branchiæ. The posterior antennæ had not changed considerably in form, they also were still but of slight length; but on the front ones a small ramification had already been developed, so that each terminated in two short branches, unequal in length. The snout was about as long as the antennæ, of considerable length therefore, and terminated very acutely. The tail had become thicker in comparison to its length. The lamina of the fan already present in the embryos was of considerable size, but represented an irregular square, which was somewhat broader behind than in front, and had a moderately deep incisure on its hinder margin. Near to the front end of this, a very small lamina, in comparison to the above plate, was moveably connected with the sixth joint of the tail on each side; it was divided by a deep narrow incision into two flaps of unequal size, but not jointed off from each other. These two small plates were the first traces of the lateral laminæ of the fan. There were still no false feet on the other joints of the tail.

In young, which were somewhat above two lines in length, five pairs of true feet already occurred. Although all these were still very small in comparison to the foot-jaws, yet a faintly indicated articulation may be recognized on them, especially on those of the three front pairs; moreover, the claws (chelæ) were already distinctly imprinted on those of the most anterior pair, and these pincers were even larger on the one than on the other. On the other hand, no branchiæ were yet decidedly evident. On the fan of the tail the side plates had become larger in proportion to the central plate, and the two unequally sized flaps of each were jointed off (abgegliedert). Only slight traces of false feet were perceptible. As to the rest, the organization of these young resembled that of those above-described.

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considerable changes, so that these specimens now exhibited great similarity with full-grown specimens. The legs, with respect to form, were perfectly developed: indeed the six front ones had already attained such a size that they exceeded the cephalothorax in length. Also that portion of the cephalothorax to which the legs were attached, had acquired, in respect to length, the ascendancy over that with which the foot-jaws and cibarian apparatus are connected. The foot-jaws were very much compressed, and possessed but a slight magnitude in comparison to the legs; they were, however, with respect to form, already similar to those of the full-grown specimens. Those of the front pair, which previously were the largest, appeared at present the smallest; and indeed they had lost in circumference, their two branches had shortened perceptibly, and on the inner ramification even the articulation was missing, while the stem was further developed. The outer branch (the palpus) on the central and posterior foot-jaws was the longest, consisting of three articulations, and had therefore acquired a joint more (the newly added joint, which was now the terminal one, subsequently separates into several.). The inner branch had become shorter on the central foot-jaws, longer on the contrary on the posterior ones, so that it now appeared altogether greater on the latter. Branchiæ were already present on the legs and posterior foot-jaws. The antennæ were of the same form as in full-grown specimens, yet the long flagellum of the posterior or outer antennæ only consisted of fifteen articulations. The eyes also were already formed as in mature specimens, and directed anteriorly. The snout had entirely disappeared. The tail, it is true, had become broader, but not thicker in the same degree, and appeared therefore rather flattened; its joints were still more sharply separated from each other; no lateral curvature was yet perceptible on it. The central lamina of the fan appeared like an oval cut from off the thinner extremity, and held together with the sixth joint of the tail by this truncated end; it had therefore quite a different form from that in the less developed young. The lateral plates of the fan had likewise, it is true, a resemblance to those of full-grown individuals, but were still quite flat and thin; moreover, those of the right and left half were still equal to each other in size.

3. *Galathæa rugosa*.—Mature embryos of this crab have a structure and form similar to those of *Pagurus*. They likewise, therefore, have only three pair of locomotive organs, and in all probability these are subsequently developed into foot-jaws. They only differ from those of *Pagurus*, in the two

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branches at the two front pairs being somewhat longer in proportion to the stem. On the fan of the tail likewise, consisting of only one plate, the incisure is very deep, so that this part is more distinctly divided into two flaps than in the mature embryo of *Pagurus*.

4. *Hyas Araneus*.—I obtained from Professor and Councillor of State Reinhardt of Copenhagen, to whom I am likewise indebted for the above-described young of *Pagurus*, several specimens of a crab-like animal, which had been caught by one of its possessors who had found a great swarm of them in the North Sea: they were probably the young of *Hyas Araneus* in two different periods of development.

The smallest were, without their snout, $1\frac{1}{2}$ lin. in length, and were very similar to those Crustacea which Thompson has already described as the young of a short-tailed crab. The dorsal shield was moderately compressed from the sides, and had in its hinder half a considerable height in comparison to the breadth, so that it might in some measure be compared to the shield of *Daphnia*. From the upper side of it proceeded a thin appendage directed upwards and backwards, which was about the same length as the dorsal shield; but forwards and downwards proceeded a simple and thin snout of about the same length. Of members which might serve for swimming three pairs occurred; and of these, as in the above-described smallest larva or young of *Pagurus*, the front pair was the largest, the hinder, entirely covered by the dorsal shield, the smallest. Each of these organs again consisted of a stem and two ramifications of which the inner was almost cylindrical and composed of five articulations, the outer one very compressed, and consisting only of two articulations. Behind them were likewise five pairs of legs, of which the front or largest was already provided with pretty far developed pincers. Yet all the legs were, in comparison to the two front pairs of joints for swimming, exhibiting themselves as foot-jaws in a lower stage of development, very small, and lay still completely hidden under the dorsal shield. Not a trace of branchiæ seemed as yet to exist. The small maxillæ and mandibulæ were similar in form to grown specimens of *Hyas*: the mandibulæ, for instance, had already a very long palpus. On the other hand, the antennæ had a form entirely different from those of full-grown specimens; however, it would lead me too far were I to describe these more minutely. The eyes were, in proportion to the whole body, enormously great, and directed sideways. The tail was much longer than the cephalothorax, the snout being left out of consideration, but was very narrow, and

branches at the two front pairs being somewhat longer in proportion to the stem. On the fan of the tail likewise, consisting of only one plate, the incisure is very deep, so that this part is more distinctly divided into two flaps than in the mature embryo of *Pagurus*.

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The smallest were, without their snout, $1\frac{1}{2}$ lin. in length, and were very similar to those Crustacea which Thompson has already described as the young of a short-tailed crab. The dorsal shield was moderately compressed from the sides, and had in its hinder half a considerable height in comparison to the breadth, so that it might in some measure be compared to the shield of *Daphnia*. From the upper side of it proceeded a thin appendage directed upwards and backwards, which was about the same length as the dorsal shield; but forwards and downwards proceeded a simple and thin snout of about the same length. Of members which might serve for swimming three pairs occurred; and of these, as in the above-described smallest larva or young of *Pagurus*, the front pair was the largest, the hinder, entirely covered by the dorsal shield, the smallest. Each of these organs again consisted of a stem and two ramifications of which the inner was almost cylindrical and composed of five articulations, the outer one very compressed, and consisting only of two articulations. Behind them were likewise five pairs of legs, of which the front or largest was already provided with pretty far developed pincers. Yet all the legs were, in comparison to the two front pairs of joints for swimming, exhibiting themselves as foot-jaws in a lower stage of development, very small, and lay still completely hidden under the dorsal shield. Not a trace of branchiæ seemed as yet to exist. The small maxillæ and mandibulæ were similar in form to grown specimens of *Hyas*: the mandibulæ, for instance, had already a very long palpus. On the other hand, the antennæ had a form entirely different from those of full-grown specimens; however, it would lead me too far were I to describe these more minutely. The eyes were, in proportion to the whole body, enormously great, and directed sideways. The tail was much longer than the cephalothorax, the snout being left out of consideration, but was very narrow, and

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nearly as thick as broad. At its extremity there was a large irregular triangular plate, which had at its posterior broad margin, or base, a moderately deep but long incisure, and at whose two posteriorly directed corners two long, thick spines directed backwards were inserted (articulated). False legs were already present, not yet divided into two branches, but nearly cylindrical. Two simple appendages, like the false feet, but of smaller size, were inserted on both sides of the lamina, representing the fan, at (into) the hinder extremity of the sixth joint of the tail.

Together with the above-described larvæ were likewise captured some others which had swum deeper. Now these were very much further developed, and already possessed a considerable resemblance to full-grown specimens of *Hyas Araneus*: for instance, the antennæ, foot-jaws and legs were of similar form and relative dimensions as in these; this was likewise the case with respect to the dorsal shield, only that this shield terminated in front in three rather long, thick spines, lying nearly in one and the same horizontal plane, of which the central one was larger than the two others. The tail, on the contrary, was proportionately much longer than in full-grown specimens, and was likewise of a moderate breadth and pretty thick. The false feet were very long in comparison to the tail, and were already provided with two branches unequal in size, and furnished with very long bristles. The fan consisted of a broad, moderately long, and posteriorly rounded plate, and of two minute and simple longish-oval laminæ, likewise inserted on both its sides at the sixth joint of the tail; these laminæ were only about half as long as the false feet of the fifth joint of the tail.

From the notices which I have here briefly communicated respecting the development of some Decapods, it therefore results that several of these animals, as first discovered and described by Thompson, undergo a very considerable and highly remarkable metamorphosis, after having thrown off their egg-shells. I therefore confess that I have done Thompson injustice in not putting faith in that discovery, relying on the history of the development of the Cray-fish, and trusting too much to analogies in the structure of full-grown Decapods; perhaps likewise led into error by the examination of very small embryos of *Eriphia spinifrons* and of *Palaemon Squilla*. It results, however, from the above communication, and from the history which I have given of the Cray-fish (and which I intend next spring partially to subject to a revision), that different Decapods quit their eggs in a different stage of

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development. *Pagurus*, *Galathæa*, and *Hyas* come out in a less developed state, since at the time of quitting the egg they do not even possess a trace of legs or branchiæ. *Astacus marinus*, on the contrary, and *Astacus fluviatilis* are at that time already provided with all the legs and branchiæ belonging to their organization. Other parts with which all Decapods appear to be then already furnished are in some at that time only slightly, in others, on the contrary, exceedingly far developed with respect to size. This relates especially to the antennæ. On the other hand, some possess in the commencement parts which are subsequently entirely lost; as, for instance, in *Astacus marinus* appendages on the legs for swimming, and in *Hyas Araneus* a considerably long spine on the upper side of its dorsal shield, while in other Decapods such parts never occur. Or, in some, parts vanish, which in others are permanent, as the snout in the *Paguri*, and the lateral laminae of the fan in *Hyas*; and other parts again undergo such considerable changes in their form, that it becomes quite different, as, for instance, central lamina of the fan, the foot-jaws, and the antennæ of several species. One of the most remarkable phænomena is, however, this;—that in Decapods which inhabit the sea the members they employ for locomotion are in the commencement so organized that they can solely or principally be used for swimming (as appears to be the case with the Lobster); in the freshwater Crab, on the other hand, when it leaves the egg those apparatus have such a structure that they can only be employed for walking.

In conclusion, I would still direct attention to the circumstance, that although several Decapods, perhaps even the greater number of them, have in the commencement with respect to the form of their members great similarity with the Schizopoda, and especially with species of *Mysis*, yet the development of the two tribes of animals is very different in several other respects.

XXXI.—*Report of the Results of Researches in Physiological Botany made in the year 1839.* By F. J. MEYEN, M.D., Professor of Botany in the University of Berlin.

[Continued from p. 144.]

FROM C. Sprengel, the writer on Rural Economy, we have received a work on Manures*, which is not only of high prac-

* Die Lehre vom Dünger, oder Beschreibung aller bei der Landwirthschaft gebräuchlicher vegetabilischer, animalischer und mineralischer Düngermaterialien, nebst Erklärung ihrer Wirkungsart, Leipzig, 1839, 8. 456 Seiten.

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